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TUNING OF OPTICAL DEVICES

Field of the Invention

The present invention relates to the thermal processing of waveguides so as to alter their properties.

Background of the Invention

The construction of planar optical waveguide devices is well known. These normally are constructed by depositing layers on top of a silicon substrate with portions of the deposited (and etched) layers being made photosensitive and subsequently being subjected to light of a wavelength selected to manipulate their optical properties. In this manner, often extremely complex optical waveguide devices can be built up on a silicon substrate.

It is desirable to provide for a system of post processing of the optical waveguide so as to tune the properties of any complex device of which the waveguide forms part.

Summary of the Invention

In accordance with a first aspect of the present invention, there is provided an optical device when subjected to localised heating, wherein the device comprises an optical waveguide and a material which absorbs a predetermined wavelength of light, the localised heating causing permanent changes in optical properties of a region of the waveguide and occurring as a result of exposing the device to light of the predetermined wavelength at an energy level sufficient to heat the material, the material being arranged to transfer at least some of the heat to the region and to minimise optically-induced alterations of the waveguide whilst the device is exposed to the light.

The localised heating can be applied by means of a laser device such as a UV or Infra Red laser device.

The device may comprise an interferometric system and the waveguide may comprise one arm of the interferometric system.

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The localised heating can be used to cause thermal relaxation, thermal diffusion or induce structural changes in the device.

In one embodiment, the localised heating is used to write a grating structure into the waveguide.

The material may be located outside the waveguide. For example, the material may comprise a substrate on which the waveguide is formed.

Alternatively, the material may be located within the waveguide.

In accordance with a second aspect of the present invention, there is provided an optical device when subjected to localised heating, wherein the device comprises an optical waveguide formed on a substrate selected to absorb a predetermined wavelength of light, the waveguide being selected to be substantially transparent to the predetermined wavelength, wherein the localised heating causes permanent changes in optical properties of a region of the waveguide, and occurs as a result of exposing the device to light of the predetermined wavelength at an energy level sufficient to heat the substrate.

The predetermined wavelength may be a sub-micron wavelength, such as 810nm. The predetermined wavelength may be absorbed by the substrate substantially at an interface with the waveguide.

Brief Description of the Drawings

Notwithstanding any other forms which may fall within

the scope of the present invention, preferred forms of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Fig. 1 illustrates schematically the process of thermal process of waveguides;

Fig. 2 illustrates an example application in a MZI type device; and

Fig. 3 illustrates an alternative form of processing of a waveguide type device.

Fig. 4 illustrates the relation between β_{stress} and β_{form} in a method embodying the present invention.

Description of Preferred and Other Embodiments

In the preferred embodiment, local thermal processing of a wafer is carried out utilizing an infra-red or UV laser device. Suitable thermally sensitive waveguides, including a negative index grating within a germanosilicate planar waveguide, can be produced by utilizing a hollow cathode plasma enhanced chemical vapour deposition (HCPECVD)process such as that outlined in M V Bazylenko, M Gross, A Simonian, P L Chu, Journal of Vacuum Science and Technology, A14, (2) pp336-345, 1996 and J Canning, D Moss, M Aslund, M Bazylenko, Election Letters, 34(4) pp366-367 (1998).

Turning now to Figure 1, the localised heating is preferably in the region of the waveguide 1 so as to alter its optical properties. Preferably, the thermal processing utilised is designed to have minimal other effects on the waveguide 1.

Hence, if a UV laser is to be utilised then it may be utilised on a silicon substrate 2 which is opaque to UV rays, as illustrated by arrow 10, whilst an IR laser may be utilised from above the waveguide 1 as illustrated by arrow 12.

The localised heating can be utilised to cause localised changes in the device 14. The changes can include thermal relaxation of internal stresses, thermal diffusion of material or thermal damage of material layers.

For example, Fig. 2 illustrates an add-drop multiplexer 10 constructed utilizing a Mach-Zehnder principle which can be initially constructed on a wafer and subsequently tuned by means of thermal rather than UV tuning of the arms at the points eg. 11, 12.

Where it is desired to utilise local radiation which may cause undesirable effects in the waveguide 100, as illustrated in Fig. 3, an opaque layer eg. 15 can be formed over the waveguide 100 so as to minimise photosensitive alterations in the area of waveguide 100.

The utilisation of local heating can have a number of uses. Firstly, as noted previously, there is its utilisation to change waveguide properties. Such utilisation would be ideal for example in Mach-Zehnder type devices. Other devices could include multimode devices wherein each arm can be thermally processed so as to adjust properties.

An alternative use for localised thermal heating is the localised heating of the substrate/wafer to control or release stresses through annealing or damaging of the wafer. E.g. it is known to construct optical waveguide devices having internal waveguide structures utilizing plasma enhanced chemical vapour deposition processes on a silicon substrate. Unfortunately, often non-symmetrical birefringence effects will result form the formation process. The first birefringent effect denoted β_{form} will be due to the circumference characteristics of the waveguide. The second effect denoted β_{stress} will be due to several stresses associated with the thermal coefficient mismatch of the substrate and deposited layer.

In an embodiment of the present invention, localised thermal heating of the above described structure could thus provide a method to alter the overall birefringence in the waveguide by either releasing existing stresses or introducing further stresses. E.g, as illustrated in Figure 4, where the "sign" of β_{stress} 200 is opposed to that of

β_{form} 202, the resultant birefringence 204 can be nullified by introducing further stresses in the direction of β_{stress} 200.

Alternatively, the localised thermal heating can be utilised as a form of annealing so as to slowly anneal the whole of a wafer whilst simultaneously measuring the waveguide properties. In this manner, the whole of the substrate can be thermally annealed on a mount with localised heating providing for a more precise annealing than that available through the utilisation of general convection heating. In this manner, the thermal annealing can be closely monitored and altered at any particular point.

The principle of localised thermal heating can be extended to the actual direct writing of thermally created device structures utilizing a small spot size for thermally induced rather than optically-induced alteration of the waveguide. Again, this can be utilised for post processing of a waveguide so as to perform tuning or, alternatively, for the construction of more complex waveguide devices.

An example application is a process of polarisation control by heating of a substrate. An ideal laser source can be a diode bar array at 810nm which is absorbed by the substrate and the waveguide. A CO/CO_2 laser can be used to heat the surface and affect the internal waveguides. Further, the devices can be tuned either at the waveguide or at the substrate. Preferably, an IR source is used so as to thermally heat and not damage the substrate.

It would be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.